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JOURNAL OF DENTAL RESEARCH®

November 1999 • Volume 78 • Number 11

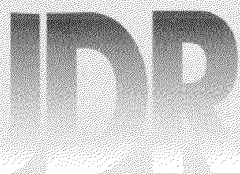
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J Dent Res 78(11): 1754-1762, November, 1999

A Controlled Daytime Challenge of Motor Performance and Vigilance in Sleep Bruxers

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Abstract. Many etiological factors have been suggested for sleep bruxism. Among these, elevated mental and physical alertness has been proposed to characterize sleep bruxers. The present study tests the hypothesis that, during the daytime, sleep bruxers are more vigilant and more prone to react to a motor command than are control subjects. Seven sleep bruxers, diagnosed polysomnographically according to validated research criteria, were matched for age and gender to seven control subjects. A simple reaction time task was selected to assess daytime vigilance and motor responsiveness. The following physiological measures were recorded: reaction time, error rate, electroencephalography, electrocardiography, electromyography, and video detection of body movements. Analysis of these variables showed no differences between groups. During the test, bruxers and controls showed a parallel decrease in EEG vigilance and heart rate over time. Frequency of orofacial and body movements was the same in both groups, and no clenching activity was observed during the experimental test. Subjects' visual analog scale ratings revealed that both controls and bruxers were more competitive after the test than before, and bruxers were slightly more anxious than controls before and after the test. Together, the results indicate that sleep bruxers are neither more vigilant nor more prone to react to a motor command during the daytime than are control subjects.

Key words: sleep bruxism, reaction time, vigilance, EEG, orofacial EMG, heart rate.

Introduction

The current definition of sleep bruxism is given by the American Sleep Disorders Association (ASDA) in its International Classification as a "stereotyped movement disorder characterized by grinding or clenching of the teeth during sleep" (ASDA, 1997). Sleep bruxism is often confused with diurnal bruxism, even though the two differ in several respects. Diurnal bruxism occurs during the daytime mainly as clenching (sustained/tonic contractions), is not normally associated with tooth grinding, and may have a different etiology (Reding *et al.*, 1966; Rugh and Ohrbach, 1988). The subjectively reported prevalence of frequent sleep bruxism, with accompanying grinding sounds, is approximately 8% in the general population (Lavigne and Montplaisir, 1994). Consequences for the patient are tooth destruction, loss of orofacial esthetics, occasional sensitive teeth, headaches, and orofacial joint and/or muscle pain or discomfort (Glaros, 1981; Rugh and Ohrbach, 1988). Although most sleep bruxers have good sleep quality, their sleeping partners often complain about the strident noise they generate (Reding *et al.*, 1968; Dettmar *et al.*, 1987; Lavigne *et al.*, 1996; Sjöholm *et al.*, 1992).

The following items are possible etiological factors and/or pathogenetic mechanisms for sleep and daytime bruxism: dental occlusion (Ramfjord, 1961), sleep arousal (Satoh and Harada, 1973; Macaluso *et al.*, 1998), neurochemistry (Lobbezoo *et al.*, 1997), tics and automatisms (Adams and Victor, 1993), and stress (Funch and Gale, 1980; Rugh and Harlan, 1988; Hicks *et al.*, 1990). However, while psycho-reactive stress may play a role in daytime clenching (Glaros, 1981; Olkinuora, 1969), its role in sleep bruxism has recently been questioned. Ambulatory recordings of sleep-bruxism-related EMG activity demonstrate a low correlation between jaw muscle activity and stress reports (Pierce *et al.*, 1995). Moreover, it has been proposed that bruxers are more anxious, hostile, and hyperactive and are characterized by elevated mental and physical alertness (Vernallis, 1955; Thaller *et al.*, 1967; Pingitore *et al.*, 1991). Most of these observations are based on studies that use subjective reports or evidence of tooth wear to assess

Received September 4, 1998; Last Revision February 12, 1999;
Accepted February 15, 1999

bruxism, but which lack objective biological recordings to confirm or reject the sleep bruxism diagnosis.

In the present study, objectively screened sleep bruxers and asymptomatic control subjects were assessed. Their diagnoses were established with laboratory recordings based on validated research criteria (Lavigne *et al.*, 1996). The hypothesis that sleep bruxers are more vigilant and more prone to react to a motor command was tested during the daytime by means of a vigilance motor task. Objective physiological measures of motor responsiveness (reaction time), vigilance (EEG), associated heart rate (ECG), and jaw muscle activity (EMG) were analyzed under blind conditions.

Materials and methods

Population and selection criteria

For this study, seven sleep bruxers and seven controls were selected. Four female and three male sleep bruxers were matched for age, gender, and education level to control subjects (Table 1). Further, all subjects had similar body mass index and craniofacial morphology, as assessed with cephalometric and dental cast measurements. Psychosocial measures (*e.g.*, whether the person practices relaxation, plays video games, etc.) were also similar for both groups (see Table 1). Subjects were selected from ongoing studies (Lavigne *et al.*, 1996; Lobbezoo *et al.*, 1997); all signed the hospital-approved consent forms and received financial compensation for their participation. To rule out baseline differences in alertness between controls and bruxers prior to the test, we conducted a one-minute recording with subjects at rest with eyes open. No statistically significant group differences in baseline levels of EEG, ECG, or EMG activities were found ($p \geq 0.5$; Table 1).

Selection criteria for sleep bruxers and controls were drawn from the literature (Rugh and Harlan, 1988; ASDA, 1997) and

have been used in previous studies (Lavigne *et al.*, 1996; Lobbezoo *et al.*, 1997). Inclusion criteria for sleep bruxers were: (1) aged 20 to 45 yrs, (2) sleeping partner reports grinding/bruxism sounds during sleep at least five nights a week in the last six months, and (3) at least one of the following: observation of tooth wear or shiny spots on restorations; report of morning masticatory muscle fatigue or pain; and/or masseteric muscle hypertrophy upon digital palpation. All subjects were studied in the sleep laboratory for two consecutive nights, with the final diagnosis of bruxism being formulated in accordance with the polysomnographic criteria reported by Lavigne *et al.* (1996). All bruxers had more than 4 bruxism episodes *per hour* and/or 25 bruxism bursts *per hour* of sleep, and presented with at least 2 episodes of grinding sounds (see Table 1). The sleep recordings were done within six months before the reaction time experiment. Among the sleep bruxism subjects, five were recorded on at least three occasions over the years, and fulfilled bruxism polysomnographic diagnosis criteria on each of these occasions, with less than 30% variation in the number of bruxism episodes *per hour*.

The exclusion criteria were: more than two missing posterior teeth (excluding third molars) or the presence of a dental prosthesis; the presence of gross malocclusion; the use of medications with possible effects on sleep or motor behavior (*e.g.*, benzodiazepines, L-dopa, neuroleptics, tricyclic-antidepressants); alcohol or drug abuse; ongoing dental or physical therapy; major neurological or psychiatric disorders; and the presence of sleep disorders such as orofacial or cervical myoclonus, narcolepsy, insomnia, periodic leg movements during sleep (PLMS, with over 20 events *per hour* of sleep), EEG epileptiform activity, and sleep apnea as confirmed during the first night recording according to ASDA criteria (ASDA, 1997).

For control subjects, inclusion criteria were that subjects be matched for age and gender with the sleep bruxer group. Exclusion criteria were the same as for the bruxism group plus any signs or symptoms suggesting the presence of bruxism (as

Table 1. Psychosocial, baseline alertness, and sleep variables

| Variables | Controls (mean \pm sd) | Sleep Bruxers (mean \pm sd) | Test | P |
|--|-----------------------------|----------------------------------|-----------------------|---------|
| Age | 26.6 \pm 6.7 | 29.9 \pm 6.4 | $t = -0.94$ (df = 12) | 0.36 |
| Gender | 4W/3M | 4W/3M | | |
| Smokers | 1 | 2 | | |
| Psychosocial variables | | | | |
| Job involving dexterity or concentration | 6 Yes | 6 Yes | | |
| Video player habits | 4 rarely 3 never | 3 rarely 3 never 1 often | | |
| Practice relaxation | 7 No | 5 No | | |
| Practice regular sport activity | 5 Yes | 4 Yes | | |
| Have practiced at least one musical instrument | 5 Yes | 5 Yes | | |
| Baseline level of alertness | | | | |
| EEG vigilance ratio | 0.76 \pm 0.21 | 0.70 \pm 0.12 | $t = 0.70$ (df = 11) | 0.50 |
| Heart rate (beats/min) | 70.8 \pm 9.5 | 68.9 \pm 13.4 | $t = 0.31$ (df = 11) | 0.76 |
| EMG masseter activity (μ V) | 4.9 \pm 1.2 | 4.6 \pm 1.5 | $t = 0.41$ (df = 12) | 0.69 |
| Sleep bruxism variables | | | | |
| Number of bruxism episodes/hour | 0.8 \pm 0.7 | 6.3 \pm 2.1 | $t = -6.5$ (df = 7.2) | < 0.001 |
| Number of bruxism episodes/night | 6.4 \pm 5.4 | 47.0 \pm 13.3 | $t = -7.5$ (df = 8.0) | < 0.001 |

seen in Table 1). All controls met the non-bruxer polysomnographic criteria described in Lavigne *et al.* (1996).

Sleep variables are shown in Table 1. Bruxism patients, in accordance with selection criteria, had significantly more bruxism episodes *per hour*, and bruxism episodes *per night*, than did control subjects ($p < 0.001$). Facial pain intensity was measured for sleep bruxers before bedtime and in the morning on a 100-mm visual analog scale. Bruxers exhibited very low facial pain both in the evening (median = 1.0; range, 0 to 12) and in the morning (median = 3.0; range, 0 to 10).

Test preparation

Before the test, all subjects were requested to refrain from smoking and drinking beverages containing caffeine (coffee, tea, Coca-Cola, etc.) for two hours to avoid the confounding influences of psychostimulants (Bates *et al.*, 1995). Upon arrival, subjects were shown the equipment and instructed in the experimental procedures, to reduce anxiety and the novelty effect of exposure to a new environment. Just before beginning the test, they were instructed to avoid talking and moving their limbs as much as possible during the test. They also scored their levels of frustration, stress, aggression, anxiety, and competitiveness on five standard 100-mm visual analog scales (VAS) (Fig. 1). To min-

imize practice effects, we administered two sets of 15 trials each before beginning the experiment (Lock and Berger, 1993).

Reaction time task

The task was administered with subjects seated in a comfortable armchair in a quiet room. Half of the subjects from each group participated in the morning (from 9:30 to 11:30) and half in the afternoon (from 14:00 to 16:00). The task was a simple reaction time test, in which performance is linked to pre-existing levels of motor and cognitive activation (Brebner and Welford, 1980). A "ready" (orange light) warning signal was followed by a "go" (green light) signal that requested the subject to press a lever as quickly as possible and to release it only at the next "ready". So that subjects' alertness levels would be maintained, a "stop" signal requesting a premature release of the lever followed the "go" signal in half the trials (13/25). Subjects were instructed always to complete the down movement of the lever before releasing it.

Experimental procedure

The time lag between the "ready" and the "go" signals varied randomly between 1 and 4 sec to prevent habituation and to minimize anticipation responses. Each set consisted of 25 trials in which "stops" were randomly presented 13 times. The interval between the "go" and the "stop" signals was constant within a set; values of 250, 300, 350, and 400 ms were used in equal proportions. Subjects were exposed to 4 sets of different go-stop latencies *per block*, randomly presented and separated by 30 sec. The test contained 4 such blocks (order of presentation differed among participants), and each block was separated by five-minute rest periods. The test lasted approximately 55 min, for a total experiment time of about 2 hrs.

Reaction times and errors rates were automatically measured by means of an in-house computer program. Since the distribution of reaction times was not normal, the median of each set from each patient was used for analysis. Reaction time dispersion was measured as the difference between the 90th and 10th centiles. Three kinds of errors were defined: (1) anticipated presses of the lever, defined as all reaction times under 100 ms (Nelson *et al.*, 1990; Oveson *et al.*, 1992; Wascher *et al.*, 1996); (2) anticipated releases of the lever; and (3) omitted, erroneous, or late releases of the lever (see Table 2). After the test, subjects responded to the same five VAS as prior to the test (Fig. 1).

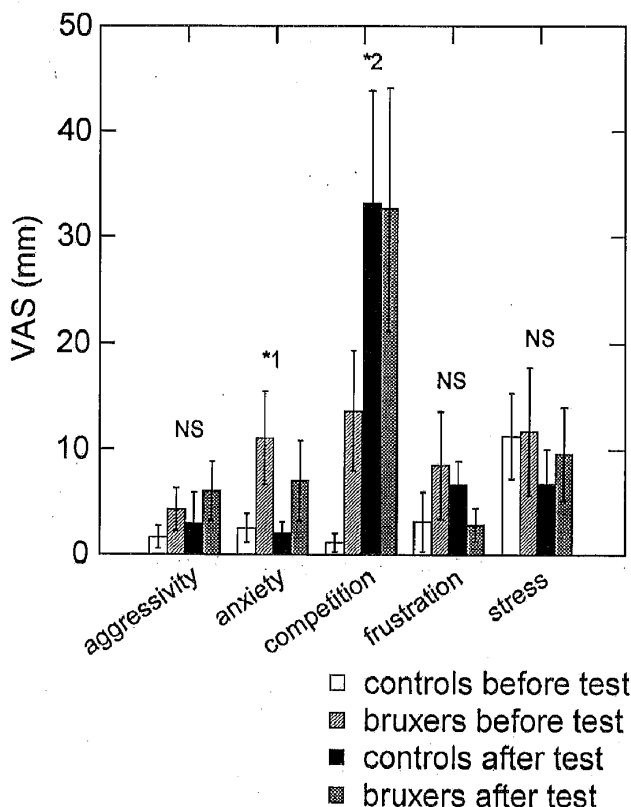


Figure 1. Psychobehavioral variables scored on visual analog scales before and after the test, for sleep bruxers ($n = 7$) and controls ($n = 7$). Means \pm SEM are shown. Repeated-measures ANOVAs were used. *1: Bruxers were more anxious than controls before and after the test ($p = 0.045$). *2: Both groups were more competitive after the test than before ($p = 0.011$). NS: Not statistically significant.

Recording and analysis of physiological data

EEG activity, heart rate, and EMG masseter activity were recorded *via* gold cup surface electrodes by means of a Grass model RPS 7C8 polygraph with the low filter set at 0.3 Hz and the high filter set at 100 Hz. Electrode impedances were kept below 10 kOhm. Prior to each recording session, the amplifiers were left on for a period of 1 hr, and then calibrated with a 50- μ V signal. EEG electrodes were fixed according to the 10-20 International System at C_3 referred to A_2 , a derivation which has been shown to provide accurate measurement of vigilance-associated changes in the EEG (Corsi-Cabrera *et al.*, 1996). The ECG electrodes were placed bilaterally on the lower ribs. Facial and body movements (e.g., smiling, arm motion; see Table 3) were recorded on video in parallel with EMG recordings of masseter muscles. The latter was

recorded bilaterally with surface bipolar electrodes placed over the area where the greatest muscle distension occurred, parallel to the direction of the muscle fibers and 15 mm apart. The acquisition of all EEG, ECG, and EMG signals was performed with Rhythm 9.0 software (Stellate Systems, 1993) at a sample frequency of 256 Hz. Data were stored on optical disk for off-line analyses.

All data analyses were conducted with the investigators blind to the clinical and polysomnographic diagnoses. For the EEG analysis, epochs without eye or movement artifacts (O'Donnell *et al.*, 1974) were selected. EEG epochs lasting 2 sec or more, totaling at least 60 sec *per set* (between 30 and 40 epochs *per set*), were analyzed. This procedure was repeated for all 16 sets for each subject. EEG epochs were then Fast-Fourier-transformed, and amplitude was obtained for the following frequency bands: delta (1.5 to 3.5 Hz), theta (4 to 7.5 Hz), alpha (8.0 to 12.5 Hz), beta (13.0 to 31.0 Hz), and beta high (31.5 to 50 Hz). An increase of alpha and theta activity with eyes open is associated with sleepiness (Torsvall and Akerstedt, 1988; Corsi-Cabrera *et al.*, 1996), whereas increased beta activity is considered to reflect cortical activation (Steriade *et al.*, 1990). Thus, estimates of vigilance and drowsiness were obtained by means of a ratio of EEG activity: $(\alpha + \theta) / (\beta + \beta \text{ high})$.

Heartbeats were identified by a standard R-peak detection algorithm; artifacts were removed by visual inspection. For each inter-beat interval, heart rate, in beats *per minute*, was calculated. The mean value of each set was subsequently used for analysis. For each set, heart rate dispersion was evaluated by the standard deviation.

Two aspects of EMG muscle activity were analyzed during the motor task: (1) baseline EMG activity of the masseter muscles at rest and (2) facial and body movements. For the EMG baseline level, a total of three 10-second epochs was captured for each set. These 10-second epochs were selected 20 sec after the beginning of the set, in the middle of the set, and 20 sec before the end of the set. We measured muscle activity during the epochs by calculating the root mean square (RMS) of the EMG channel using the following equation: $\text{RMS} = \sqrt{(\sum x^2) / n}$ (see Lavigne *et al.*, 1997). Facial and body movements were manually detected from the EMG by the presence of large bursts on the masseter channel. Once identified, these movements were verified by the video recordings. In this manner, facial or body movement artifacts were identified and scored (Table 3).

Statistical analyses

Distribution of errors on the reaction time task as well as the numbers of orofacial and body movements on the EMG were not nor-

Table 2. Number of mistakes during the experimental test

| Variables | Controls median [5-95%] | % | Sleep Bruxers median [5-95%] | % | Test | P |
|--|-------------------------------|----------------|------------------------------------|----------------|------------------|------|
| Premature presses of the lever (Reaction time under 100 msec from the "go" signal) | 8 [6-166] | 7.8 n = 219 | 9 [3-93] | 8.5 n = 239 | $U_{M-W} = 23.5$ | 0.90 |
| Premature releases of the lever (Reaction time under 100 msec from the "stop or ready" signal) | 5 [1-25] | 2.0 n = 56 | 4 [0-20] | 1.6 n = 46 | $U_{M-W} = 27.0$ | 0.75 |
| Omitted, erroneous or late releases of the lever | 6 [0-11] | 1.3 n = 36 | 2 [0-10] | 0.9 n = 24 | $U_{M-W} = 29.5$ | 0.52 |

Table 3. Number of orofacial and body movements

| Variables | Controls (n = 7) median [5-95%] | Sleep Bruxers (n = 6) median [5-95%] | Test | P |
|--|------------------------------------|---|------------------|------|
| Orofacial movements (EMG and video scoring) | 14 [7-32] | 11.5 [0-16] | $U_{M-W} = 29.5$ | 0.22 |
| % swallowing | 22.7 | 17.9 | | |
| % smiling | 23.4 | 11.9 | | |
| % talking | 4.0 | 6.0 | | |
| % lip movements | 50.0 | 64.2 | | |
| % clenching | 0.0 | 0.0 | | |
| Total (n) | 122 | 58 | | |
| Body movements | 11 [7-56] | 12.5 [5-43] | $U_{M-W} = 25.5$ | 0.52 |
| % head motion | 50.3 | 37.3 | | |
| % arm motion | 8.4 | 11.9 | | |
| % body motion | 27.3 | 42.4 | | |
| % scratching | 14.0 | 8.5 | | |
| Total (n) | 143 | 98 | | |

mal. Thus, controls and sleep bruxers were compared for these variables by means of Mann-Whitney U tests. Sleep bruxism variables between the two groups were compared by two-sample *t* tests (separate variance estimates).

VAS measures were evaluated by repeated-measures ANOVAs, with Group as a between-subjects variable, and Before/After the test as a within-subjects variable; one ANOVA was performed for each of the five VAS questions.

Reaction time, reaction time dispersion, EEG amplitude ratio $[(\alpha + \theta) / (\beta + \beta \text{ high})]$, heart rate, heart rate standard deviation, and masseter EMG activity (RMS) were analysed by repeated-measures ANOVAs, with Group as a between-subjects variable, and Block (1-4) and Sequence within the block (1-4) as within-subjects variables. All ANOVA results involving within-subjects variables used the Greenhouse-Geisser epsilon correction procedure. Corrected *p* values and epsilon (ϵ) are reported for these analyses. Single degree-of-freedom polynomial contrasts were also performed.

A *p*-value ≤ 0.0125 was considered significant for all statistical

tests to reduce the risk of type I error due to the number (4) of physiological variables analyzed (Bonferroni correction). Analyses were performed with Systat 6.0 for Windows.

Results

Visual analog scales

Only one of the five psychobehavioral variables scored showed a significant difference before and after the test (see Fig. 1). Sleep bruxers were slightly more anxious than controls pre- and post-test [$F(1,11) = 5.09$; $p = 0.045$]. Both controls and sleep bruxers were more competitive after the test than before [$F(1,11) = 9.203$; $p = 0.011$].

Reaction times

Fig. 2a shows the group mean values of median reaction times to press the lever at the "go" signal for the 16 sets. The repeated-measures ANOVA revealed that there were no statistical differences between controls and bruxers [$F(1,12) = 0.036$; $p = 0.853$]. The mean reaction time was 230.0 ms for

controls and 227.3 ms for bruxers. The Block and Sequence effects were both significant [Block, $F(3,36) = 12.116$; $p = 0.001$, $\epsilon = 0.503$; Sequence, $F(3,36) = 5.085$; $p = 0.009$, $\epsilon = 0.800$]. Polynomial contrasts revealed that the Block effect was mainly linear [$F(1,12) = 14.305$; $p = 0.003$], accounting for 87.8% of the variability across the four blocks. The Sequence effect was also mainly linear [$F(1,12) = 7.694$; $p = 0.017$]. None of the interactions was statistically significant at the 0.0125 level. Reaction times were not influenced by the 4 different "go-stop" latencies presented *per* block (repeated-measures ANOVA, [$F(3,36) = 0.652$; $p = 0.55$, $\epsilon = 0.770$]).

Since a significant interaction between Sequence and Group was observed for reaction time dispersion [$F(3,36) = 7.503$; $p = 0.002$, $\epsilon = 0.771$], a repeated-measures ANOVA was performed for each block. Bruxers' reaction times tended to be less dispersed than controls' for the first block only [$F(1,12) = 6.785$; $p = 0.023$].

Error rates during the experimental test

No significant differences were found between the sleep bruxers and controls on any measure of reaction time error during the experimental test (see Table 2).

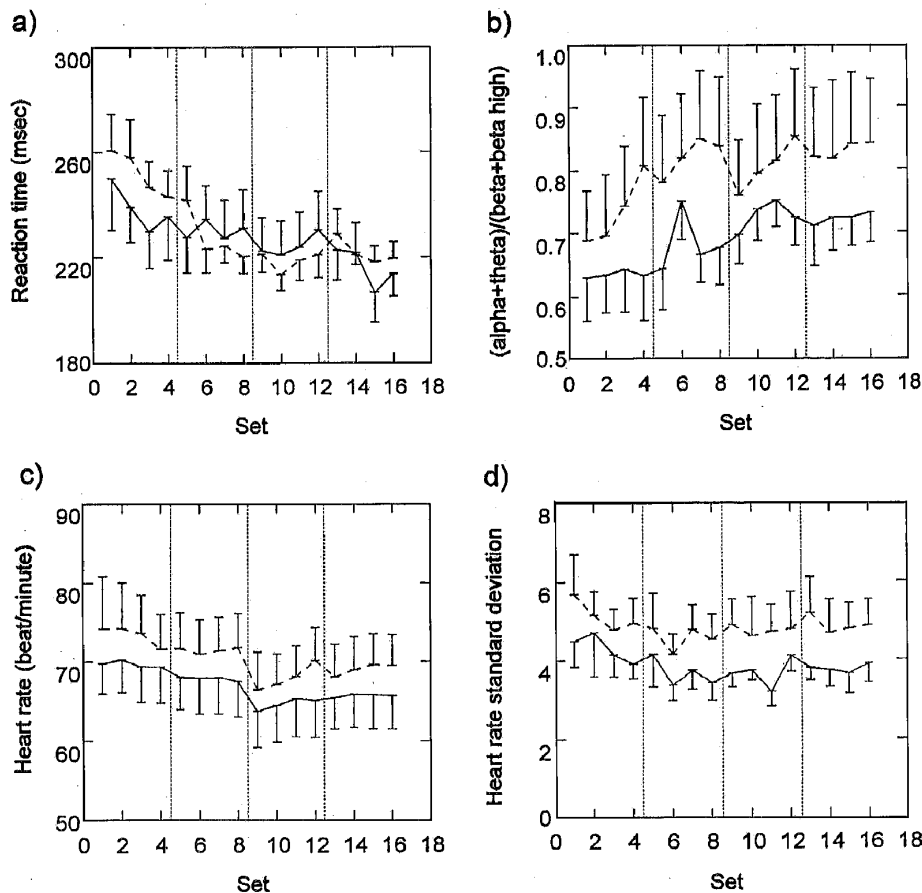


Figure 2. Reaction time (a), EEG vigilance ratio (b), heart rate (c), and heart rate standard deviation (d) throughout the test for sleep bruxers ($n = 7$) and controls ($n = 7$). Blocks are separated by dotted lines. Means \pm SEM are shown on the graphs. No significant differences between groups were observed by repeated-measures ANOVAs.

Electroencephalography

The ratio (alpha+theta)/(beta+beta high) was used to measure vigilance, with an increase in the ratio indicating a reduction in vigilance. No significant difference was found in EEG-defined vigilance between sleep bruxer and control groups [$F(1,12) = 0.89$; $p = 0.36$]. Both groups, however, showed a parallel decrease in EEG vigilance over Blocks [$F(3,36) = 7.42$; $p = 0.002$, $\epsilon = 0.790$] (see Fig. 2b). Polynomial contrasts revealed that this decrease was mainly linear [$F(1,12) = 14.384$; $p = 0.003$]; 81% of the variability across Blocks could be attributed to the effect. No significant interactions were observed.

Heart rate

Fig. 2c shows heart rate values during the test. The repeated-measures ANOVA revealed no differences between sleep bruxer and control groups [$F(1,12) = 0.31$; $p = 0.585$], even though both groups showed heart rate decreases over Blocks [$F(3,36) = 19.18$; $p < 0.001$, $\epsilon = 0.612$]. Overall, this decrease was

mainly linear, accounting for 76.6% of the variability over Blocks [$F(1,12) = 22.18$; $p = 0.001$]. The cubic component accounted for an additional 10% of the variability over Blocks [$F(1,12) = 29.11$; $p < 0.001$].

Heart rate dispersion values are shown in Fig. 2d. No statistically significant main effect was observed *via* the repeated-measures ANOVA [Group: $F(1,12) = 1.448$; $p = 0.252$]. There were also no statistically significant interaction effects.

Level of muscle activity during the test and facial mimic

Levels of EMG activity over the 16 different sets are displayed in Fig. 3. It can be observed that this activity is slightly higher for bruxers than for control subjects, although the difference is not statistically significant [$F(1,12) = 2.387$; $p = 0.148$]. Block and Sequence effects did not differentiate between the groups; neither was any of the interaction effects significant.

The specificity of muscle activity, as detected on the masseter EMG channels, was verified with video recordings. Many orofacial and body movements were observed, but no differences between groups in frequency of either orofacial [$U = 29.5$; $p = 0.22$] or body movements [$U = 25.5$; $p = 0.52$] were noted (see Table 3). No clenching activity was observed during the motor task. One sleep bruxer was eliminated from these analyses because the videotape recording was damaged, and the patient's face could not be evaluated for the entire test period.

Discussion

This study was performed for an objective evaluation of the alertness and the propensity to accelerate the rate of execution of mental and physical functions of sleep bruxers (Pingitore *et al.*, 1991). To achieve this goal, we recorded the reaction times, error rates, and EEG, ECG, and EMG activities of sleep bruxers and control subjects.

Sleep bruxers and control subjects were carefully selected, and their clinical diagnoses were confirmed by polysomnography (Lavigne *et al.*, 1996). Subjects were closely matched for age and psychosocial habits (Table 1) to eliminate possible confounding variables (Reding *et al.*, 1966; Goulet *et al.*, 1993). Furthermore, the baseline levels of alertness for the bruxer and control groups were similar, as determined by EEG, EMG, and HR values. The sleep bruxers in this study reported a very low level of facial pain. The relationship between pain and increased vigilance or motor activity is not clearly established. In a previous study, myofascial pain patients exhibited significantly slower reaction times than did controls (Intrieri *et al.*, 1994). Moreover, sleep bruxers with pain have been shown to present 40% fewer bruxism episodes *per* hour of sleep (Lavigne *et al.*, 1997). Sleep bruxers and controls with sleep disorders (*e.g.*, insomnia, apnea) were excluded from this study based on the first night's recording. The elucidation of possible interactions of these sleep disorders with sleep bruxism is beyond the scope of this study.

Psychological variables

The attitudes of both groups of subjects toward the task, and their changes in attitude while executing it, were evaluated.

Whereas the VAS estimates of aggression, competitiveness, frustration, and stress did not differentiate between the groups, sleep bruxers were slightly more anxious than controls, and both groups were more competitive after the test. Previously, Vernallis (1955) and Olkinuora (1972) noted an anxiety trait in sleep bruxers, while Walsh (1965) suggested that sleep bruxers have difficulty in controlling their frustration and anxiety. Pingitore *et al.* (1991) also mentioned the need for sleep bruxers to be competitive. Even though the higher anxiety observed for our sleep bruxers seems consistent with these studies, an important distinction remains: The anxiety evaluated in our study was task-related and cannot be extended to subjects' everyday lives. Thus, our present results have little bearing on studies showing no increased anxiety, aggression, or hostility among bruxers (Reding *et al.*, 1968; Simon *et al.*, 1997) in everyday life.

Motor responsiveness

According to Pingitore *et al.* (1991), bruxers should be faster than controls during a motor task. In our study, motor responsiveness of sleep bruxers and controls was compared by means of a simple reaction time task that allows for direct measurement of motor reaction time without the decision phase included in a complex motor task (Frowein, 1981).

Reaction time showed a linear decrease throughout the test for both groups, and no difference was found between groups. This decrease could be due to practice or habituation, although Feinstein *et al.* (1994) and Versavel *et al.* (1997) mention that a practice effect has limited influence during a simple motor task.

We avoided stimulus anticipation during the test by pre-

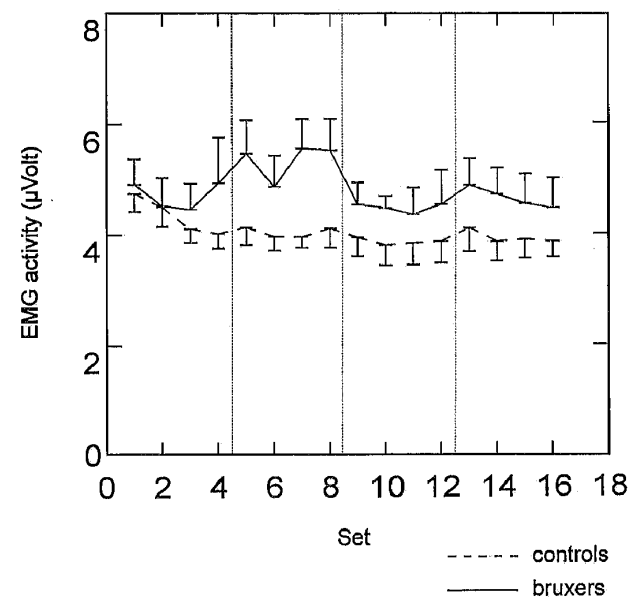


Figure 3. Mean EMG activity (\pm SEM) throughout the test for sleep bruxers ($n = 7$) and controls ($n = 7$). Blocks are separated by dotted lines. The repeated-measures ANOVA revealed no significant differences between bruxers and controls.

senting stimuli randomly 1 to 4 sec after the "ready" signal (Crabtree and Antrim, 1988; Oveson *et al.*, 1992). Reaction times obtained during this test are similar to those observed by Nelson *et al.* (1990) and Rammsayer *et al.* (1995), who obtained reaction times of 263 ms and 269 ms, respectively, in similar studies with normal subjects.

Vigilance

Bruxers should display extreme mental alertness, according to Pingitore *et al.* (1991). In our study, the alertness of sleep bruxers and controls was assessed by error rates, reaction times, EEG, and ECG.

Vigilance measurements are widely used with sleep apnea patients. These patients have poor sleep quality and exhibit decreased vigilance during the day. This decreased vigilance can lead to increased reaction times during a complex motor task, wider reaction time dispersions, and an increased number of errors during the test (Bédard *et al.*, 1991; Oveson *et al.*, 1992; Jokinen *et al.*, 1995). In our study, reaction times showed a parallel linear decrease for both groups, possibly due to a practice effect. The reaction time dispersion tended to be lower for sleep bruxers during the first block, but was not statistically significant with the error-adjusted *p*-value. Furthermore, the number of errors was similar for both groups. Corsi-Cabrera *et al.* (1996) and Lorenzo *et al.* (1995) found a positive correlation between reaction time and hours of wakefulness for sleep-deprived patients. The number of errors increased, but not significantly (Lorenzo *et al.*, 1995).

A vigilance decrease throughout the test was observed on the EEG recordings. The vigilance ratio ($\alpha + \theta$)/($\beta + \beta_{high}$) showed a linear vigilance decrease during the test for both groups. EEG recordings during a simulated radar watch task have shown similar increases in α and θ activity, decreases in β activity, and concurrent performance decrements as a function of time (O'Hanlon and Beatty, 1977). Also, increased α and θ waves have been shown to be related to vigilance decreases (Corsi-Cabrera *et al.*, 1996; Lorenzo *et al.*, 1995; Torsvall and Akerstedt, 1987, 1988; Ota *et al.*, 1996), such as an observed increase in sleepiness of train drivers during the night (Torsvall and Akerstedt, 1987). The latter authors, in 1988, also reported increased α and θ power prior to somnolence during a 45-minute vigilance performance test executed during the night. Corsi-Cabrera *et al.* (1996) and Lorenzo *et al.* (1995) observed a linear increase in α and θ activity with accumulating hours of wakefulness in sleep-deprived subjects. The contamination of β waves with muscular activities and eye movements has been described (O'Donnell *et al.*, 1974; Matousek and Petersen, 1983). In the present experiment, EEG traces with muscular artifacts were discarded. Furthermore, patients were not required to move their eyes during execution of the task.

Both groups showed a heart rate decrease during the test, with no difference between groups. According to Lacey and Lacey (1973) and Posner and Raichle (1994), heart rate should decrease during a vigilance task. Deceleration in heart rate has been observed during a visual tracking task (Mascord and Heath, 1992) and during long-distance dri-

ving tasks (O'Hanlon and Kelly, 1977). Heart rate dispersion did not vary significantly during the test, contrary to Mascord and Heath (1992), who observed an increase in heart rate variability during experimental sessions.

EMG and video recordings

These data were recorded to compare the facial muscle activities of sleep bruxers and controls during the execution of a reaction time task during the day. In contradiction to what has been reported during sleep periods, neither sleep bruxers nor controls clenched their teeth during this test. Both groups exhibited similar levels of baseline muscle activity during the test. Katz *et al.* (1989) previously emphasized the importance of discriminating between facial expressions and masticatory muscle activities, a distinction which was achieved in this experiment with the video recordings. Physiological variables such as age, sex, and facial morphology have been shown to influence the level of masticatory muscle activity (Lund and Widmer, 1989). The impact of these variables was minimized in this study, since controls and bruxers were matched. A previous study with diurnal bruxers and controls has shown that bruxers exhibit higher masseter EMG activity both at rest and during mild and strong stress conditions (Rao and Glaros, 1979). However, it has been suggested that diurnal and nocturnal bruxism are two different parafunctions with different etiologies (Rugh and Ohrbach, 1988).

Sample size estimations

Although significant differences between groups in reaction time and vigilance measures were not observed in our study, it is possible that real differences do exist that could be revealed if a larger sample were used. Based on the differences observed between groups and the statistical criteria of $\alpha = 0.05$ and $\beta = 0.20$ for the estimation of sample size, at least 70 subjects for each group would be needed for the reaction time, EEG ratio, and heart rate measures. If such large populations are in fact needed to prove that small differences in reaction time and vigilance are real, it is reasonable to assume that the differences between groups are negligible.

In conclusion, no differences between sleep bruxers and controls were found in our study for the reaction time, reaction errors, electroencephalography, electrocardiography, and electromyography measures. These results indicate that sleep bruxers are neither more motor-responsive nor more vigilant than control subjects, as tested during a daytime reaction time task. It is unknown whether these conclusions are also true for patients with other parafunctional activities, such as daytime bruxism, but the methods of the present study could be adapted to the testing of such patient groups.

Acknowledgments

We thank Dr. Dominique Petit for her help with quantified analyses of the EEG. This study was supported by the Medical Research Council of Canada (MRCC). Maryse

Major received a postgraduate scholarship from the "Fonds de la Recherche en Santé du Québec" (FRSQ).

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